CLAIMS

We claim:

1. A method comprising:

wirelessly receiving a signal;

detecting a start of packet (SOP) from the received signal using at least one SOP detection criterion for a packet that conforms to a wireless networking standard;

determining a plurality of metrics from the received signal; and

in the case an SOP is detected, using at least two of the plurality of metrics to determine an initial timing for a received packet.

2. A method as recited in claim 1, wherein a packet according the wireless networking standard includes a preamble, and wherein detecting the SOP includes using at least one of the set of SOP methods that comprises:

detecting that a threshold was exceeded by the average received signal power;

detecting that a threshold was exceeded by the average power rise of the received signal; and

detecting that a threshold was exceeded by a measure of the quality of the correlation of the input signal with a known part of the preamble.

3. A method as recited in claim 1, wherein the set of SOP methods of which at least one is used for detecting the SOP further includes:

detecting a rise in a weighted sum of the measure of the average received signal power and the measure of the correlation of the input signal with the known part of the preamble.

4. A method as recited in claim 3, wherein the measure of the correlation quality is a comparison measure of the instantaneous correlation power with the average correlation power in the recent past.

5. A method as recited in claim 3, wherein the measure of the correlation quality is a measure of the correlation power normalized by the power of the received signal.

6. A method as recited in claim 1, wherein a packet according the wireless networking standard includes a preamble, and wherein detecting the SOP includes:

determining a logical function of at least one of the set of logical indicators including:

that a threshold was exceeded by the average received signal power;

that a threshold was exceeded by the average power rise of the received signal;

that a threshold was exceeded by a measure of the quality of the correlation of the input signal with a known part of the preamble; and

that a threshold was exceeded by a weighted sum of the measure of the average received signal power and the measure of the correlation of the input signal with the known part of the preamble.

7. A method as recited in claim 1, wherein a received packet conforms to at least one wireless standard, wherein a packet according each of the wireless networking standards includes a preamble, and wherein detecting the SOP includes:

for each wireless networking standard, determining a corresponding logical function of at least one of the set of logical indicators including:

that a threshold was exceeded by the average received signal power;

that a threshold was exceeded by the average power rise of the received signal;

that a threshold was exceeded by a measure of the quality of the correlation of the input signal with a known part of the preamble; and

that a threshold was exceeded by a weighted sum of the measure of the average received signal power and the measure of the correlation of the input signal with the known part of the preamble,

and

determining the OR of the plurality of the corresponding logical functions.

8. A method as recited in claim 7, wherein the measure of the correlation quality is a comparison measure of the instantaneous correlation power with the average correlation power in the recent past.

9. A method as recited in claim 6, wherein the measure of the correlation quality is a measure of the correlation power normalized by the power of the received signal.

10. A method as recited in claim 1, wherein a packet according to the wireless networking standard includes a preamble that has a first part that includes a series of periodic symbols and a second part, and wherein determining the plurality of metrics includes determining at least two of the set of metrics that comprises:

a measure of the carrier to noise ratio (CNR);

a measure of the received signal power;

a measure of the autocorrelation of the input signal at the period of the symbols;

a measure the correlation of the input signal with at least one of the short symbols; and

a measure of the correlation of the input signal with the start of the second part of the preamble,

wherein determining the initial timing uses at least two indicators of the set of indicators that includes:

whether or not a measure of the carrier to noise ratio (CNR) is within a CNR range;

that a threshold was exceeded by a measure of the change of the averaged received signal power;

that a range was reached by a measure of the autocorrelation of the input signal at the period of the symbols;

that a threshold was exceeded by a measure of the correlation of the input signal with at least one of the short symbols; and

that a change was detected in a measure of the correlation of the input signal with the start of the first part of the preamble, and

that a threshold was exceeded by a measure of the correlation of the input signal with the start of the second part of the preamble,

and wherein determining the initial timing determines the timing from at least one of:

the time a measure of the rise in the received signal power peaks;

the time a measure of the autocorrelation of the input signal at the period of the symbols changes to indicate the time of end of the series of periodic symbols;

the time a measure the correlation of the input signal with at least one of the short symbols peaks to indicate an SOP time; and

the time a measure the correlation of the input signal with at least one of the short symbols changes to indicate the time of end of the series of periodic symbols; and

the time a measure of the correlation of the input signal with the start of the second part of the preamble peaks to indicate the time of the start of the second part.

11. A method as recited in claim 10, wherein the at least two metrics may further include:

in the case the wireless standard uses OFDM, a measure of the short-term power spectral density of the received signal, and

in the case the wireless standard uses OFDM, a measure of interference between OFDM symbols,

wherein the set of indicators further includes:

in the case the wireless standard uses OFDM, that a change was detected in a measure of the power spectral density; and

in the case the wireless standard uses OFDM, that a range was reached by a measure of interference between OFDM symbols

and wherein the at least one measure used for determining the initial timing may further include:

in the case the wireless standard uses OFDM, the time a change occurs in a measure of the short-term power spectral density of the received signal, and

in the case the wireless standard uses OFDM, the time when a measure of the interference between OFDM symbols is lowest.

12. A method as recited in claim 11, wherein determining the measure of interference between OFDM symbols includes:

determining a measure of the channel impulse response during the second part of the preamble, and

filtering the determined impulse response with a filter having an impulse response of relatively small equal to the start of the second part of the preamble.

13. A method as recited in claim 11, wherein the set of possible metrics of which at least at least two metrics are determined includes a measure of the delay spread, and wherein the set of possible indicators of which at least two indicators are used in determining the initial timing includes whether or not a measure of the delay spread is within a delay spread range.

14. A method as recited in claim 11, wherein which of the indicators is used in the initial time determining is determined by a priori simulation under a set of different CNR and delay spread conditions.

15. A method as recited in claim 11, wherein which of the indicators is used in the initial time determining is determined by a priori experiments under a set of different CNR and delay spread conditions.

16. A method as recited in claim 11, wherein which of the indicators is used in the initial time determining is determined by a combination of a priori experiments and a priori simulations under a set of different CNR and delay spread conditions.

17. A method as recited in claim 11, wherein determining the measure of the CNR includes computing the ratio of the received power during the presence of a packet and the received signal power a relatively small time before the packet arrived.

18. A method as recited in claim 17, wherein each of the received powers before and after the packet is computed on a logarithmic scale, such that computing the ratio includes subtracting the received power during the presence of a packet and the received signal power the relatively small time before the packet arrived.

19. A method as recited in claim 11, wherein the symbols have substantially constant envelope, and wherein determining of the autocorrelation includes:

determining an approximation to the phase of the autocorrelation by phase shift key (PSK) detecting the input signal, and

determining a monotonic function of the difference of the PSK detected signal and a delayed version of the PSK detected signal.

20. A method as recited in claim 19, wherein determining of the autocorrelation further includes:

filtering the determined monotonic function of the difference.

21. A method as recited in claim 23, wherein the input signal is provided as a set of received signal samples in rectangular coordinates, and wherein determining the measure

of the correlation of the input signal with the start of the second part of the preamble includes:

filtering the received signal samples using a FIR filter whose coefficients are time-reversed, complex conjugated samples of start of the second part, quantized to rectangular coordinates of ±1.

22. A method as recited in claim 11, wherein determining the measure of the correlation of the input signal with the start of the second part of the preamble includes calculating the amplitude of the correlation, and comparing the amplitude of the correlation with an average of recent samples of the correlation amplitude.

23. A method as recited in claim 11, wherein the wireless networking standard is one of the IEEE 801.11 OFDM standards according to which the first part of the preamble includes a periodic series of short symbols and the second part includes long symbols and a guard interval.

24. A method as recited in claim 11, wherein the determining of the initial timing includes:

detecting whether or not a measure of the CNR is in a CNR range wherein a first metric of the set of metrics is expected to be effective, and

using the first metric for the initial timing determining only if it is detected that the measure of the CNR is in the CNR range.

25. A method as recited in claim 24, wherein the first metric is the measure of autocorrelation, and such that determining of initial timing uses that a range was reached by the autocorrelation measure only if it is detected that the measure of the CNR is in the CNR range.

26. A method as recited in claim 25, wherein determining the initial timing uses the time of the peak of the measure of the correlation of the input signal with the start of the second part of the preamble.

27. A method comprising:

wirelessly receiving a signal;

detecting a start of packet (SOP) from the received signal using at least one SOP detection criterion for a packet that conforms to a wireless networking standard, a packet according to the wireless networking standard including a preamble that has a first part that includes a series of periodic symbols and a second part; and

in the case an SOP is detected,

detecting whether or not a measure of the CNR is in a CNR range wherein it is expected that a change of a measure of the autocorrelation of the input signal at the period of the symbols is effective to indicate the time of end of the series of periodic symbols; and

determining an initial timing for a packet using that a threshold was exceeded by a measure of the correlation of the input signal with the start of the second part of the preamble, further using the time of a peak in the correlation of the input signal with the start of the second part of the preamble, and, if it is detected that the measure of the CNR is in the CNR range, further using that a range was reached by the autocorrelation measure.

28. An apparatus comprising:

a radio receiver to receive a signal and output a received signal;

a start of packet (SOP) detector coupled to the radio receiver to detect an SOP from a received signal using at least one SOP detection criterion for a packet that conforms to a wireless networking standard;

a processing circuit coupled to the radio receiver to determine a plurality of metrics from the received signal; and

an initial time determining circuit coupled to the SOP detector and the processing circuit, the initial time determining circuit using at least two of the

plurality of metrics to determine an initial timing for a received packet in the case an SOP is detected.

29. An apparatus as recited in claim 28, wherein a packet according the wireless networking standard includes a preamble, and wherein the SOP detector detects by one of the set of SOP methods that comprises:

detecting a rise in the average received signal power;

detecting a rise in the average power rise of the received signal;

detecting a rise in a measure of the quality of the correlation of the input signal with a known part of the preamble; and

detecting a rise in a weighted sum of the measure of the average received signal power and the measure of the correlation of the input signal with the known part of the preamble.

30. An apparatus as recited in claim 28, wherein the SOP detect an SOP using different sets of at least one SOP criterion for each of a set of at least one wireless networking standard that an arriving packet may conform to,

wherein a packet according each of the at least wireless networking standard includes a preamble, and wherein the SOP detector detects a packet by detecting whether any logical function corresponding to any of the at least one standard is true:

each corresponding function being of at least one of the set of logical indicators for each standard, each set of logical indicators comprising:

that a threshold was exceeded by the average received signal power;

that a threshold was exceeded by the average power rise of the received signal; and

that a threshold was exceeded by a measure of the quality of the correlation of the input signal with a known part of the preamble.

31. An apparatus as recited in claim 28, wherein the SOP detect an SOP using different sets of at least one SOP criterion for each of a set of at least one wireless networking standard that an arriving packet may conform to,

wherein a packet according each of the at least wireless networking standard includes a preamble, and wherein the SOP detector detects a packet by detecting whether any logical function corresponding to any of the at least one standard is true:

each corresponding function being of at least one of the set of logical indicators for each standard, each set of logical indicators comprising:

that a threshold was exceeded by the average received signal power;

that a threshold was exceeded by the average power rise of the received signal;

that a threshold was exceeded by a measure of the quality of the correlation of the input signal with a known part of the preamble; and

that a threshold was exceeded by a weighted sum of the measure of the average received signal power and the measure of the correlation of the input signal with the known part of the preamble.

32. An apparatus as recited in claim 28, wherein a packet according to the wireless networking standard includes a preamble that has a first part that includes a series of periodic symbols and a second part, and wherein the processing circuit includes at least two of the set that comprises:

a circuit to determine a measure of the carrier to noise ratio (CNR);

a circuit to determine a measure of the rise in the received signal power;

an autocorrelation circuit to determine a measure of the autocorrelation of the input signal at the period of the symbols;

a symbol correlation circuit to determine a measure the correlation of the input signal with at least one of the short symbols; and

a second correlation circuit to determine a measure of the correlation of the input signal with the start of the second part of the preamble,

wherein the initial timing determining circuit determines the initial timing using at least two indicators of the set of indicators that comprises:

whether or not a measure of the carrier to noise ratio (CNR) is within a CNR range;

that a threshold was exceeded by a measure of the rise in the received signal power to indicate an SOP time;

that a range was reached by a measure of the autocorrelation of the input signal at the period of the symbols;

that a threshold was exceeded by a measure of the correlation of the input signal with at least one of the short symbols; and

that a threshold was exceeded by a measure of the correlation of the input signal with the start of the second part of the preamble,

and wherein the initial timing determining circuit determines the initial timing from at least one of:

the time a measure of the received signal power exceeds a signal power threshold to indicate an SOP time;

the time a measure of the autocorrelation of the input signal at the period of the symbols changes to indicate the time of end of the series of periodic symbols;

the time a measure the correlation of the input signal with at least one of the short symbols peaks to indicate an SOP time; and

the time a measure of the correlation of the input signal with the start of the second part of the preamble peaks to indicate the time of the start of the second part.

33. An apparatus as recited in claim 32, wherein the symbols have substantially constant envelope, and wherein autocorrelation circuit includes a phase shift key (PSK) detector to determine a coarsely quantized phase estimate, and a difference circuit to determine a monotonic function of the difference of the coarsely quantized phase estimate and a delayed version of the coarsely quantized phase estimate.

34. An apparatus as recited in claim 33, wherein the autocorrelation circuit further includes a filter to filter the determined monotonic function of the difference.

35. An apparatus as recited in claim 32, wherein the wireless networking standard is one of the IEEE 801.11 OFDM standards according to which the first part of the preamble includes a periodic series of short symbols and the second part includes long symbols and a guard interval.

36. An apparatus as recited in claim 32, wherein the initial time determining circuit includes:

a detector to detect whether or not a measure of the CNR is in a CNR range wherein a first metric of the set of metrics is expected to be effective,

and wherein initial time determining circuit uses the first metric for the initial timing determining only if it is detected that the measure of the CNR is in the CNR range.

37. An apparatus as recited in claim 36, wherein the first metric is the measure of autocorrelation, and such that initial time determining circuit uses that a range was reached by the autocorrelation measure only if it is detected that the measure of the CNR is in the CNR range.

38. An apparatus as recited in claim 37, wherein initial time determining circuit uses the time of the peak of said measure of the correlation of the input signal with the start of the second part of the preamble.

39. An apparatus comprising:

a radio receiver to receive a signal;

a start of packet (SOP) detector coupled to the radio to detect an SOP from the received signal using at least one SOP detection criterion for a packet that conforms to a wireless networking standard, a packet according to the wireless networking standard including a preamble that has a first part that includes a series of periodic symbols and a second part;

a CNR detector coupled to the SOP detector and to the radio receiver to detect, in the case an SOP is detected, whether or not a measure of the CNR is in a CNR range wherein it is expected that a change of a measure of the autocorrelation of the input signal at the period of the symbols is effective to indicate the time of end of the series of periodic symbols;

an autocorrelator coupled to radio receiver to determine the measure of the autocorrelation of an input signal at the period of the symbols;

an autocorrelation detector coupled to the autocorrelator to detect a change in the measure of the autocorrelation;

a correlator coupled to the radio receiver to determine a measure of the correlation of the input signal with the start of the second part of the preamble; and

an initial time determining circuit coupled to the CNR detector, the autocorrelation detector, and to the correlator to determine an an initial timing for a packet using that a threshold was exceeded by a measure of the correlation of the input signal with the start of the second part of the preamble, further using the time of a peak in the correlation of the input signal with the start of the second part of the preamble, and, if it is detected that the measure of the CNR is in the CNR range, further using that a range was reached by the autocorrelation measure.

40. An apparatus comprising:

means for wirelessly receiving a signal;

means for detecting a start of packet (SOP) detector from a received signal using at least one SOP detection criterion for a packet that conforms to a wireless networking standard;

means for determining a plurality of metrics from the received signal; and

means for determining an initial timing for a received packet in the case an SOP is detected, the initial time determining means using at least two of the plurality of metrics to determine the initial timing.

41. An apparatus as recited in claim 40, wherein a packet according to the wireless networking standard includes a preamble that has a first part that includes a series of periodic symbols and a second part, and wherein the means for determining the plurality of metrics includes at least two of the set that comprises:

means for determining a measure of the carrier to noise ratio (CNR);

means for determining a measure of the rise of received signal power;

means for determining a measure of the autocorrelation of the input signal at the period of the symbols;

means for determining a measure the correlation of the input signal with at least one of the short symbols; and

means for determining a measure of the correlation of the input signal with the start of the second part of the preamble,

wherein the initial timing determining means uses at least two indicators of the set of indicators that comprises:

whether or not a measure of the carrier to noise ratio (CNR) is within a CNR range;

that a threshold was exceeded by a measure of the rise of the received signal power to indicate an SOP time;

that a range was reached by a measure of the autocorrelation of the input signal at the period of the symbols;

that a threshold was exceeded by a measure of the correlation of the input signal with at least one of the short symbols; and

that a threshold was exceeded by a measure of the correlation of the input signal with the start of the second part of the preamble,

and wherein the initial timing determining means further uses at least one of:

the time a measure of the rise of the received signal power peaks to indicate an SOP time;

the time a measure of the autocorrelation of the input signal at the period of the symbols changes to indicate the time of end of the series of periodic symbols;

the time a measure the correlation of the input signal with at least one of the short symbols peaks to indicate an SOP time; and

the time a measure of the correlation of the input signal with the start of the second part of the preamble peaks to indicate the time of the start of the second part,

to provide a measure of the initial timing.

42. An apparatus as recited in claim 41, wherein the symbols have substantially constant envelope, and wherein the autocorrelation means includes means to phase shift key (PSK) detect for determining a PSK detected signal, and means for determining a monotonic function of the difference of the PSK detected signal and a delayed version of the PSK detected signal.

43. An apparatus as recited in claim 41, wherein the wireless networking standard is one of the IEEE 801.11 OFDM standards according to which the first part of the preamble includes a periodic series of short symbols and the second part includes long symbols and a guard interval.